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RESEARCH

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Thermal Separation of Solids Contaminated with Organics

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Of the items listed in Table 11 that should be included, the two most often omitted items are mobilization/demobilization and process residual disposal. The mobilization costs can vary greatly by technology and/or vendor. For a remediation of less than 10,000 tons, these costs become very significant. The quantity and fate of process residuals can have a dramatic effect on processing cost. Virtually all onsite treatment technologies product process residuals that require off-site disposal. Residuals such as spent carbon, scrubber blowdown, condensed organics, condensed water, washwater, spent chemicals, etc. must all be accounted for. Disposal of these process residuals can account for 2 to 20% of the processing cost.

The CWM X•TRAX process "typical" processing cost is $125 to $225 per ton of feed. Actual site specific processing costs will depend on the volume of material to be treated (tons), moisture content, type of soil (particle size), level and type of contamination and treatment standard. These cost estimates include all of the line items listed in Table 4-1 except for permitting and analytical charges as indicated in the last column.

Table 11. Box B Line Items for Preliminary Cost Estimates

Item	Should be Included	In CWM Estimate
Permitting	N	N
Mobilization and Demobilization	Y	Y
Additional Feed Pretreatment	Y	Y
Labor (Operating and supervisory)	Y	Y
Utilities	Y	Y
Chemicals	Y	Y
Other Consummables (PPE, carbon)	Y	Y
Process Residual Disposal	Y	Y
Maintenance	Y	Y
Capital (Depreciation, rental, etc.)	Y	Y
Analytical Charges	N	N

THERMAL SEPARATION OF SOLIDS CONTAMINATED WITH ORGANICS

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1. INTRODUCTION

The market for soil treatment technologies is expanding rapidly. One source estimates the contaminated soils market to be $200-300 billion in the next 30 to 40 years.[1] This market expansion is driven by at least three factors. First is the Superfund program, of which contaminated soils comprise the majority of wastes requiring remediation at hundreds of sites across the country. A second driving force is the "landbans" (40 CFR Part 268) which will prohibit the landfilling of many contaminated soils because of their organic content. The third driving force is the recent legislation by many states requiring that real estate must be certified as non-contaminated before the transfer takes place.

Many technologies can potentially be used to treat organically-contaminated soils. These include solidification/stabilization, bioremediation, soil washing, in situ vacuum extraction, solvent extraction, thermal desorption, in situ and ex situ vitrification, incineration and others.

[1] "Industry Tests New Technologies for Soil Cleaning," Environmental Business Journal Vol. III, No. 2, February 1990.

This paper discusses the patented X*TRAX™ thermal desorption (separation) process developed by Chemical Waste Management, Inc. (CWM).

2. SYSTEM DESCRIPTION

X*TRAX is a separation process to remove volatile or semi-volatile compounds from a solid matrix. Thermal energy is the driving force used to affect the separation. The process flow diagram is presented in Figure 1.

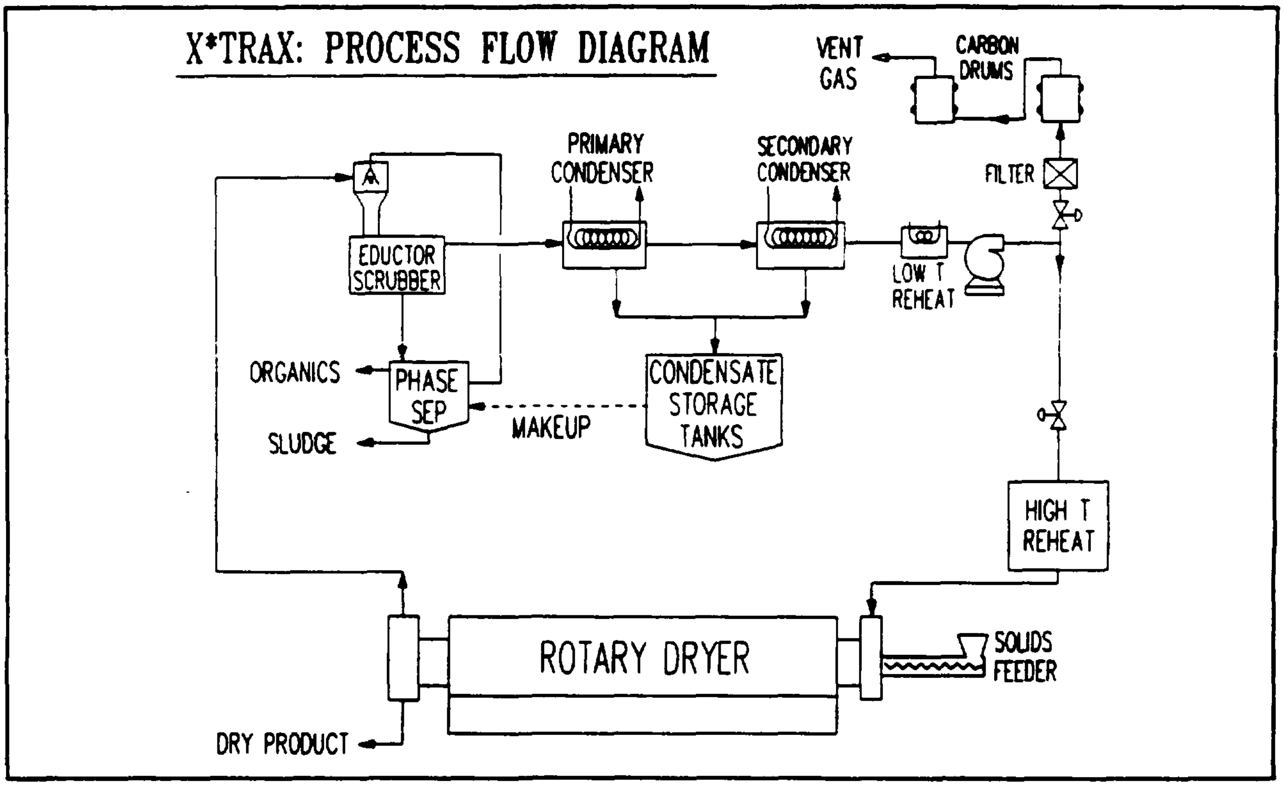


Figure 1

Feed material, which can be either a solid or pumpable sludge, is fed into the dryer. The dryer is an externally fired rotary kiln. It is essentially a sealed rotating cylinder with the feed material tumbling inside and the heat source (propane burners) on the outside. Since the dryer is externally fired, the combustion products do not contact the waste material (feed) being processed. The use of an externally fired dryer has two distinct advantages. First, and most important, is that the combustion gases do not contact the feed material. Propane is a readily available clean burning fuel. Air permits for vent stacks from propane combustors are easily obtained, usually without any required APC devices. This allows the APC devices for X*TRAX to be one tenth to one hundredth the size of that for an equivalent capacity incinerator. In addition, the small volume of nitrogen carrier gas discharged makes cleaning it to very high standards quite inexpensive. The second advantage of external firing is that it makes the X*TRAX system a separation process, not an incinerator because no organic combustion occurs. It is usually much easier to permit a waste separation process than a waste incinerator.

The heated solids are discharged from the dryer as a powdered or granular dry material. For most applications, water will be mixed with the exiting solids to cool them and to prevent dusting. By adding reagents at this point, metal containing wastes can be stabilized with the reagent cost being the only additional expense. The water will normally be condensed water from the gas treatment portion of X*TRAX.

Nitrogen is used as a carrier gas to prevent fires, and reduce the potential for oxidative reactions. The carrier gas first passes through a liquid scrubber where entrained solid particles are removed and the gas stream is cooled to its saturation temperature. The scrubber also removes a portion of the volatilized organics. The recirculated scrubber water continuously passes through a phase separator. The phase separator collects any condensed light organic from the liquid surface and continuously discharges a bottom sludge containing solids, water and organics. The sludge is dewatered using a filter press. The dewatered solids are either returned to the feed stream or disposed of.

The scrubbed gas passes to the first heat exchanger where it is cooled to 10°F above ambient temperature. This heat exchanger will produce the bulk of the liquid condensate. The carrier gas now goes to a second heat exchanger where it is cooled to 40°F. The liquid condensates from both heat exchangers are mixed and allowed to gravity separate. Organics are removed for disposal. The condensed water is used to cool and dedust the treated solids exiting the dryer.

The 40°F carrier gas now contains some residual moisture and organics that were present in the feed at levels equal to or less than their equilibrium saturation concentration at 40°F. The carrier gas then passes to a recirculation blower. After the blower, 5 to 10% of the carrier gas is vented, and the remainder is heated to 400-700°F before returning it to the dryer. The process vent gas stream passes through a particulate filter (2 micron) and then through a carbon adsorber, where at least 80% of the remaining organics will be removed. Actual practice has shown removal efficiencies by the carbon ranging from 89 to 98%. This gas is then vented to the atmosphere.

2.1 Laboratory Unit

CWM has been performing laboratory treatability studies since 1988. As of October 1, 1991, 64 tests have been completed for 31 different clients on 48 different samples. Only 5 of these tests were performed on surrogate wastes. The testing is performed under the RCRA Treatability Exemption and a TSCA R&D permit.

The laboratory unit can process 1 to 3 kg/hr of material. It is actually a small continuous pilot unit, simulating the full scale hardware in almost every feature. A typical test run lasts eight to twelve hours. Two to three hours at each steady state condition are required to produce enough material for the analytical needs and two to three hours are required for start-up and to reach steady state after changing one of the operating parameters. Figure 2 shows the laboratory unit at CWM's R&D facility in Geneva, IL.

Figure 2. Laboratory X•TRAX™

2.2 Pilot System

The pilot X*TRAX system is a mobile unit mounted on two semi trailers; one containing the dryer and another containing the gas treatment system. The dryer is 24-inch diameter, 20 feet heated length, with 10 propane burners. The pilot system has a nominal capacity of 5 tons per day. The pilot system was used to provide design data on capacity, material handling, and gas system performance for the full scale system. It has been and continues to be used to provide treatability and emissions data on candidate waste streams, and is available for the performance of demonstrations.

The pilot system became operational in January, 1988. Since then it has been used to test over 90 tons of materials, including: 59 tons of simulated RCRA wastes, 5.5 tons of mixed radioactive/hazardous waste, 20 tons of TSCA regulated PCB soils, and 4.4 tons of RCRA materials. Figure 3 shows the pilot system on location at the DOE's Oak Ridge, TN facility.

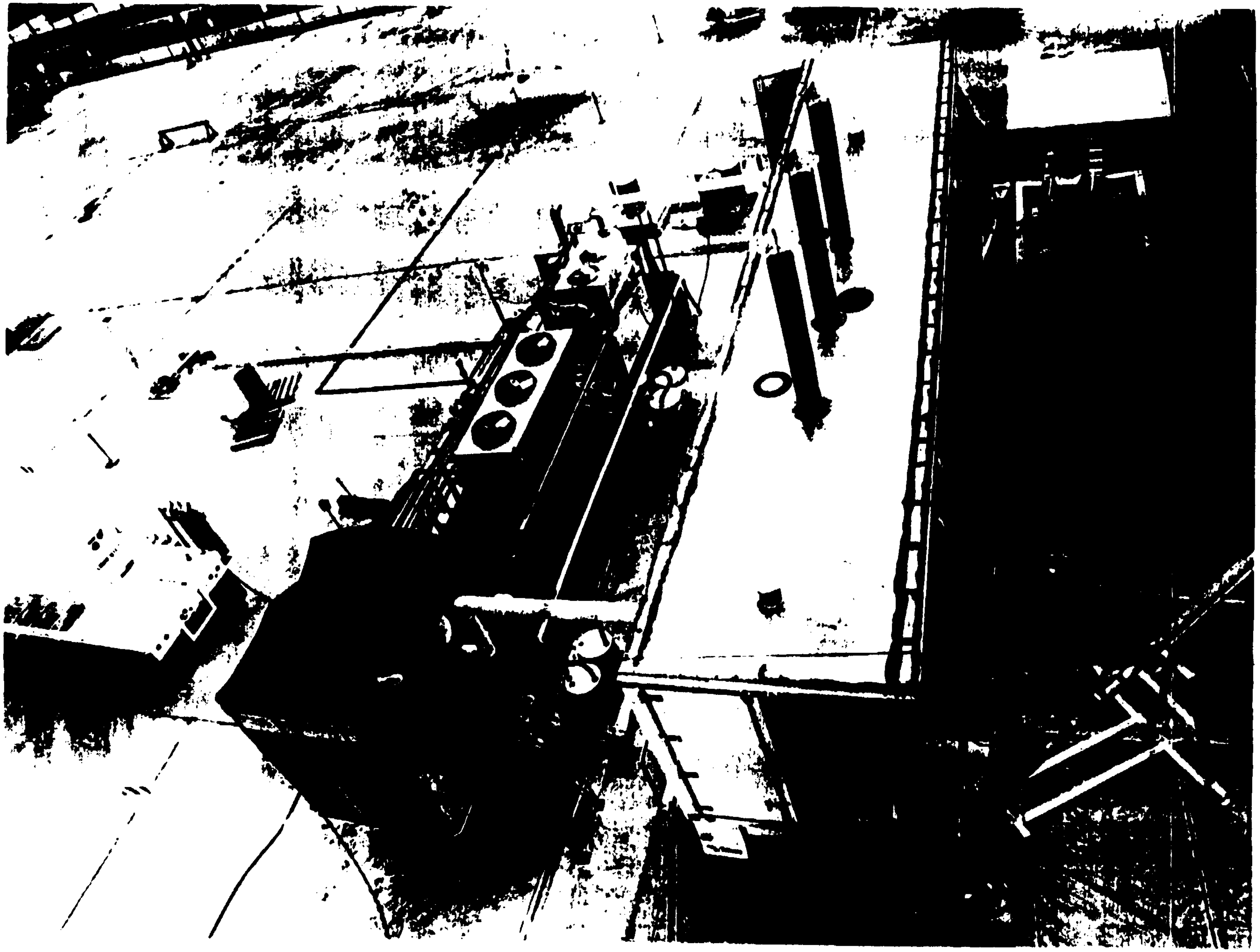


Figure 3. Pilot X•TRAX™

The pilot system is presently installed at CWM's Kettleman Hills Facility in central California. The system is operated under a variety of permits at Kettleman. The most basic of these is an operating permit from Kings County, allowing CWM to have an air emission source. CWM also has a variance from the California Department of Health Services (DHS) to treat non-RCRA wastes such as California special wastes. The testing on PCB materials was conducted under a R&D permit from the EPA's TSCA branch, which expired in February of 1990.

A RCRA RD&D permit was granted by both the Region IX EPA and California DHS in November of 1990. The permit was issued for one year, and a one year extension has been requested to allow testing to continue until November of 1992.

SCALE BACK TO 8-HR DAY 40 TON/DAY

2.3 X*TRAX Model 200 Full Scale Production System

The X*TRAX Model 200 is a full scale production system that was constructed for onsite cleanup of contaminated soil. The system is capable of treating 125 tons per day of contaminated soil with a moisture content of 20%. Like the pilot system, the Model 200 has a rotary dryer and a gas treatment system. The Model 200 is fully transportable, consisting of three semi trailers, one control room trailer, eight equipment skids and various pieces of removable equipment. Figure 4 is a photograph of the Model 200 system. The area required for the equipment measures 120 ft. by 120 ft.

All of the equipment has been designed for over the road transport anywhere in the U.S. or Canada. The dryer is the largest of its kind that can be transported over the road. The components are mobilized to the project site and assembled using a relatively small 15 ton crane. Approximately three to four weeks are required to completely install the equipment. Concrete footings are not usually required; however concrete housekeeping pads may be required. All skids or trailers that normally contain liquids have integral liquid containment curbs for spill control.

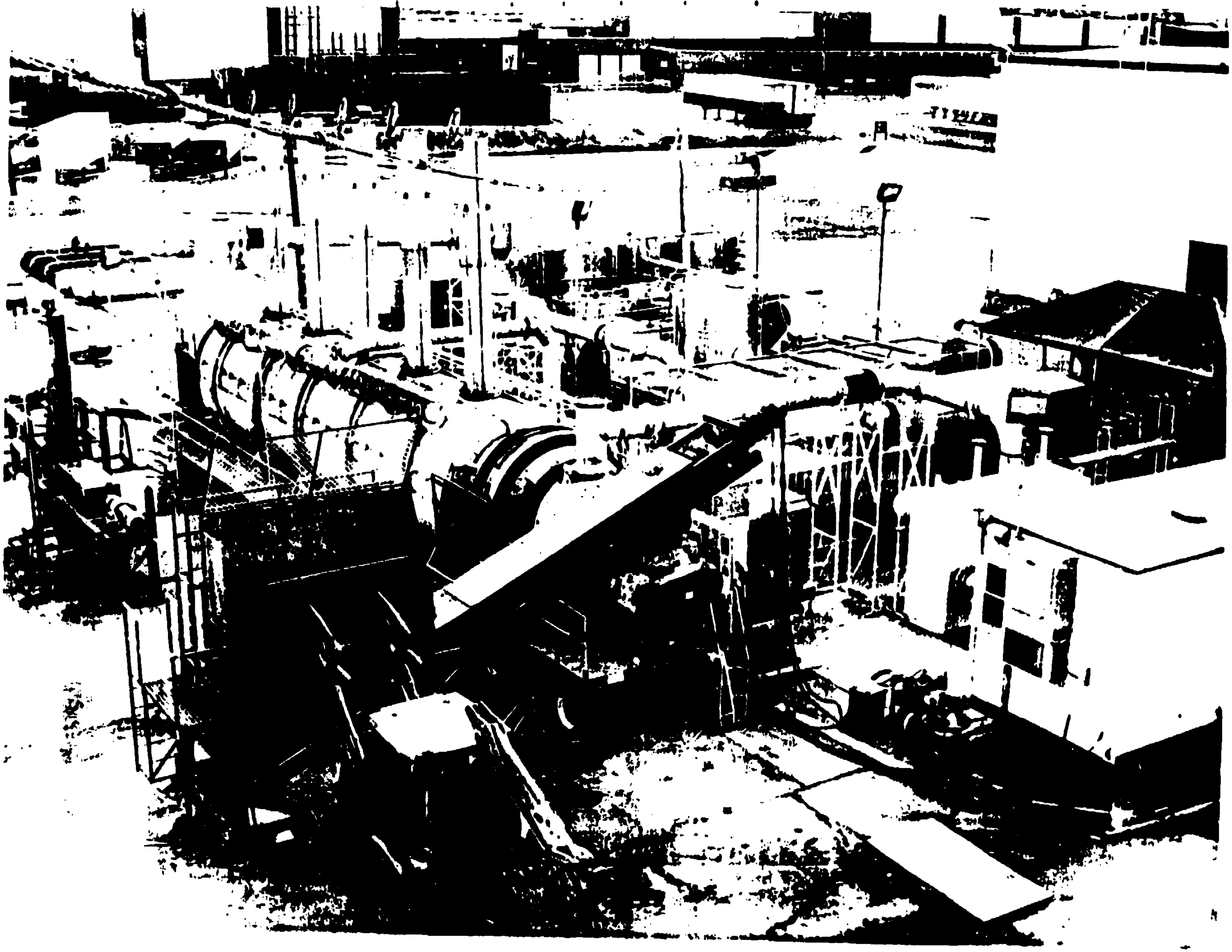


Figure 4. X•TRAX™ Model 200

The system requires 700 amps of three phase, 460 volt electric power, propane storage tanks, and a liquid nitrogen storage tank. The system can be operated from a diesel generator if electric power is not available at the site. Water is required only for housekeeping purposes.

The first Model 200 will be used at the ReSolve Superfund Site in North Dartmouth, MA starting in early 1992. Approximately 35,000 tons of PCB-contaminated soil will be processed at this site. A Superfund Innovative Technology Evaluation (SITE) demonstration will also be performed during the remediation.

CWM plans to build additional Model 200 X*TRAX systems as required.

3. RESULTS FOR VARIOUS CONTAMINANTS

Over the past three and one-half years, CWM has tested scores of different contaminated soils in the lab and pilot X*TRAX systems. The contaminants have included a broad spectrum of organic chemicals regulated by RCRA and TSCA, as well as certain toxic metals. Under its CS&D program, EPA has published lists of contaminants of interest for soil, organized by similar chemicals (i.e. treatability) groups, numbered W01 through W12.[2] This section presents treatment results according to the CS&D groupings.

These results are for a variety of solid matrices, primarily soil, but also including pond sludge and filter cakes. The reported results represent only a fraction of the data generated in CWM's ongoing testing program. With the exception of results marked with an asterisk, all of these results have been for regulated waste materials or contaminated soils. Marked results are for spiked soils.
X*TRAX has been generally able to reduce the W01 group contaminants to less than 1 ppm.

[2]Quality Assurance Project Plan for Characterization, Sampling and Treatment Tests Conducted for the Contaminated Soil and Debris (CS&D) Program, U.S. EPA, April 30, 1990.

Table 1. X•TRAX Test Results - Halogenated Non-Polar Aromatic Compounds (W01)

Constituent	Concentration (ppm)		Test Scale
	Feed	Product	
Chlorobenzene	61.8	0.006	Pilot*
Chlorobenzene	110	0.180	Lab*
1,2-Dichlorobenzene	537	0.074	Pilot*
1,2-Dichlorobenzene	82	<0.33	Lab*
1,4-Dichlorobenzene	78.4	0.001	Pilot*
Hexachlorobenzene	79.2	0.30	Pilot*
Hexachlorobenzene	7.9	0.40	Lab
Pentachlorobenzene	11.6	<0.33	Lab
1,2,4-Trichlorobenzene	24.8	<0.33	Lab
4,4'-DDD	320	1.3	Lab
4,4'-DDE	32	0.57	Lab

For the W02 group, X•TRAX has achieved significant PCB reductions, generally with residual levels less than 25 ppm and frequently less than 10 ppm, even when starting at over 1,000 ppm total PCBs. These residual PCB concentrations represent very low risk levels. Aroclors that have been tested include 1016, 1242, 1248, 1254 and 1260.

Results for the W03 group generally show high removal efficiencies frequently exceeding 99%. It is interesting to note the difference in residual pentachlorophenol concentrations for the two samples that had approximately 500 ppm. This disparity indicates that treatability studies are required even if prior experience exists.

Table 2. X*TRAX Test Results - Dioxins/Furans, PCBs and Their Precursors (W02)

Constituent	Concentration		Test Scale
	Feed	Product	
Total PCB	12	<2	Lab
Total PCB	50	<2	Lab
Total PCB	97	<2	Lab
Total PCB	120	3.4	Pilot
Total PCB	630	17	Pilot
Total PCB	1,600	4.8	Pilot
Total PCB	2,800	19	Pilot
Total PCB	7,800	24	Pilot

Table 3. X*TRAX Test Results - Halogenated Phenols, Cresols and Other Polar Aromatics (W03)

Constituent	Concentration (ppm)		Test Scale
	Feed	Product	
3,3'-Dichlorobenzidine	1,716	<0.66	Lab
Pentachlorophenol	497	<1.6	Lab*
Pentachlorophenol	586	7.8	Lab
Pentachlorophenol	17.9	<0.63	Lab

Table 4. X*TRAX Test Results - Halogenated Aliphatic Compounds (W04)

Constituent	Concentration (ppm)		Test Scale
	Feed	Product	
1,2-Dichloroethane	38	0.62	Lab*
Tetrachloroethene (PCE)	118	<0.25	Pilot
Tetrachloroethene (PCE)	109	<.005	Lab
Tetrachloroethene (PCE)	150	0.094	Lab*
Trichloroethene (TCE)	28	<0.25	Pilot
Trichloroethene (TCE)	103	<0.005	Lab

Results for the W04 group are outstanding, as would be expected for these highly volatile chemicals.

Only limited results have been obtained to date for the W05 and W06 groups. This does not mean that X*TRAX is not applicable to these contaminants, just that they have not been frequently found in the soils CWM has tested. Leachable levels for chlordane were below the TCLP method detection limit for the sample with 5.1 ppm of chlordane.

Table 5. X*TRAX Test Results - Halogenated Cyclic Aliphatics, Ethers, and Ketones (W05)

Constituent	Concentration (ppm)		Test Scale
	Feed	Product	
Chlordane	210	5.1	Lab
Chlordane	4,286	3.4	Lab

Table 6. X*TRAX Test Results - Nitrated Aromatic and Aliphatic Compounds (W06)

Constituent	Concentration (ppm)		Test Scale
	Feed	Product	
Nitrobenzene	43	<0.66	Lab

Table 7. X*TRAX Test Results - Simple Non-Polar Aromatics and Heterocyclics (W07)

Constituent	Concentration (ppm)		Test Scale
	Feed	Product	
Toluene	12	<0.10	Lab
Toluene	45	<0.024	Lab
Toluene	136	2.2	Pilot
Xylenes	68	<0.50	Pilot
Xylenes	77	<0.10	Lab
Benzene	7.2	0.025	Lab
Benzene	980	<0.21	Lab
Ethylbenzene	40	<0.50	Pilot
Ethylbenzene	92	<0.024	Lab
Styrene	44	<0.050	Lab*
Styrene	200	<0.005	Lab

Residual levels for W07 have also been quite low. These levels can be compared to clean-up guidelines from underground storage tank removals, which are frequently in the 10 to 15 ppm total BTEX range, with benzene levels as low as 25 ppb or less.

Table 8. X•TRAX Test Results - Polynuclear Aromatics (W08)

Constituent	Concentration (ppm)		Test Scale
	Feed	Product	
Acenaphthene	16.7	<0.33	Lab
Anthracene	9.2	0.37	Pilot
Benzo(a)anthracene	20	0.51	Pilot
Chrysene	15	0.42	Pilot
Fluoranthene	36.6	<0.33	Lab
Fluoranthene	51	0.79	Pilot
2-Methylnaphthalene	170	2.1	Lab
Naphthalene	50	<0.33	Lab
Naphthalene	450	7.9	Lab
Phenathrene	27	0.18	Lab
Phenathrene	56	0.47	Pilot
Pyrene	57	1.3	Pilot

Results for the W08 group, PNAs or PAHs, have been that levels can usually be reduced to below 10 ppm, and frequently to below 1 ppm. CWM has seldom found these compounds at levels over 100 ppm in contaminated soils.

Although the W09 group compounds have widely ranging volatility, results have been that they are typically reduced to below 1 ppm in the treated material.

Table 9. X*TRAX Test Results - Other Non-Halogenated Polar Organic Compounds (W09)

Constituent	Concentration (ppm)		Test Scale
	Feed	Product	
2-Butanone (MEK)	27.6	1.5	Pilot
4-Methyl-2-pentanone (MIBK)	16.8	0.102	Pilot
Bis(2-ethylhexyl)phthalate	373	<2	Pilot
Bis(2-ethylhexyl)phthalate	2,630	<0.33	Lab*
Butylbenzyl phthalate	151	0.13	Pilot
Di-n-butyl phthalate	77	0.31	Pilot

Table 10. X*TRAX Test Results - Volatile Metals (W11)

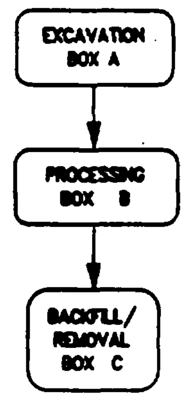
Constituent	Concentration (ppm)		Test Scale
	Feed	Product	
Mercury	1.0	0.16	Lab
Mercury	3.1	0.20	Lab
Mercury	5,100	1.3	Lab

With respect to the "volatile" metals group W11, CWM has recently tested X*TRAX for removal of elemental mercury from soil. The result of reducing soil with 5,100 ppm to 1.3 ppm residual mercury is excellent, demonstrating good potential for this application. No indication of metals reduction has been found for other metals, including arsenic. CWM has also tested materials where mercury was not the contaminant of concern, but was detected at over 1 ppm in the feed. These results are also given. This is considered by CWM to be an advantage for X*TRAX. For example, a soil with over 3.8% lead was pilot tested, with no reduction in the soil's lead level and a barely detectable air emission ($5x10^{-8}$ % of the lead fed to the unit).

This material would probably have been rejected for incineration based on its lead content.

4. TREATMENT COST

Trying to compare treatment costs for different technologies or even a single technology from different suppliers is difficult at best. For onsite ex-situ treatment technologies, it is suggested that the process be divided into three tasks or boxes. The first box (A) is the excavation and debris removal. The cost for box A is usually fairly uniform for each suitable technology and should not be included in the preliminary cost estimate for various technologies or suppliers. The third box (C) includes backfilling or removing the treated solids. Since each technology or vendor will normally be required to treat to the same standards, the cost for box C need not be included. The middle box (B) is the highly variable one, since it is the actual processing cost.



To compound the problem, preliminary or "typical" cost estimates for box B are not always presented on the same basis. Table 11 presents the major line items that may or may not be included in preliminary or "typical" cost estimates. Two of the cost items, permitting and analytical charges, should not be included in preliminary on non-site specific cost estimates. Permitting is highly site specific and can range over two orders of magnitude. The analytical charges are also highly variable, and usually cannot be determined until after the permitting. Analytical charges for an onsite remediation could range from $300 to $5,000 per day. At 150 tons per day, we see that the analytical charges could add anywhere from $2.00 per ton to over $30.00 per ton. Also, the analytical charges will be the same for each supplier of a given technology, and should have a fairly narrow range for different technologies at a given site.